

just a few of the available visualization tools. These tools are capable of processing and displaying large quantities of information. Often, however, operators do not have the time to go through the entire volume of reconstructed data to determine the optimal parameters of the three-dimensional image generation. Commonly default sets of parameters are utilized to produce the MPR, MIP, VR, or SR images.

[0005] The predefined 3D image orientations and number of 3D images often leave significant room for improvement. Diagnostic quality can be significantly degraded by overlapped structures due to inappropriate selection of the 3D casting angles. Anatomical structures often cannot be clearly visualized in the resulting 3D image due to this overlapping. This often not acceptable for proper diagnosis. Although parameters may be adjusted and the number of 3D images may be modified, often such reconstruction may result in an undesirable expense of time and cost. Furthermore, reprocessing of the original two-dimensional data sets may become impractical or impossible if the original imaging data is archived or deleted. Clinical studies may find such reprocessing is not an available option.

[0006] It would therefore be highly desirable to have a three dimensional imaging apparatus and method that would automatically optimize the resulting three-dimensional visualization such that adequate 3D casting angles are utilized. It would further be beneficial for such an apparatus and method to optimize the number of 3D images produced such that an adequate visualization of the anatomical structure was provided.

Summary of Invention

[0007] It is, therefore, an object of the present invention to provide an apparatus and method for automatically optimizing a medical three-dimensional visualization such that adequate 3D casting angles are achieved. It is a further object of the present invention to provide an apparatus and method optimizing a medial three-dimensional visualization such that an adequate number of 3D images are produced. In accordance with the objects of the present invention, a method for automatically optimizing medical three-dimensional visualizations is provided. The method includes isolating a plurality of anatomical structures within the 3D visualization. Calculating the number of ray intersects intersecting more than one of said plurality of anatomical structures

for a plurality of casting angles is then performed. Selecting a casting angle that minimizes said ray intersects to allow for the selection of an optimized three-dimensional visualization. Finally the optimized medical three-dimensional visualization is displayed from the selected casting angle. Other objects and features of the present invention will become apparent when viewed in light of the detailed description of the preferred embodiment when taken in conjunction with the attached drawings and appended claims.

Brief Description of Drawings

[0008] FIGURE 1 is an illustration of a medical three-dimensional visualization illustrated in a non-optimized orientation; FIGURE 2 is an illustration of a medical three-dimensional visualization illustrated in an optimized orientation; FIGURE 3 is an illustration of the medical three-dimensional visualization illustrated in Figure 2, the three-dimensional visualization rendered from the optimized casting angle; FIGURE 4 is an illustration of a method of automatically optimizing a medical three-dimensional visualization in accordance with the present invention; FIGURE 5 is an illustration of an alternate embodiment of a method of automatically optimizing a medical three-dimensional visualization in accordance with the present invention; FIGURE 6 is an illustration of a further embodiment of a method of automatically optimizing a medical three-dimensional visualization in accordance with the present invention; and FIGURE 7 is an illustration of an improvement to the embodiment of a method of automatically optimizing a medical three-dimensional visualization illustrated in Figure 4.

Detailed Description

[0009] Referring now to Figure 1, which is an illustration of a medical three-dimensional visualization 10 in accordance with the present invention. The visualization 10 is intended to encompass any of a wide variety of three-dimensional visualizations known in the medical community including, but not limited to, MPR, MIP, VR, and SR visualizations. These visualizations are commonly reconstructed groupings of two-dimensional images 12 of anatomical image 14 created using CT, MR or other modalities. The anatomical image 14 commonly is comprised of a plurality of anatomical structures 16 such as the blood vessels filled with contrast medium 18

illustrated in Figures 1–3. Although blood vessels 18 have been utilized for illustrative purposes, it should be understood that the present invention is applicable to a wide range of anatomical images 14 representing a wide variety of anatomical structures 16.

[0010] When the resultant medical three-dimensional visualization 10 is displayed to an examining physician, it is illustrated from the perspective of a casting angle 20. The casting angle 20 illustrated in Figure 1 is a non-optimized casting angle 22. It can be understood to be non-optimized because the casting rays 24 intersect the plurality of anatomical structures 16, creating ray intersects 25, such that they would undesirably overlap when viewed by the examining physician. Since the three vessels 18 are nearly co-planar from this non-optimized casting angle 20, the vessels 18 cannot be clearly visualized in the resulting three-dimensional visualization 10 due to the overlapping. The present invention selects an optimized casting angle 26 as illustrated in Figure 2 such that the casting rays 24 intersect the plurality of anatomical structures 16 such that the resulting overlap of the three-dimensional visualization 10 is minimized. The three-dimensional visualization 10 can then be projected on a display 28 at this optimized casting angle 26 as illustrated in Figure 3. It should be understood that although the figures utilize casting angles 20 orientated parallel to the reconstructed two-dimensional dataset, the orientation need not be limited to parallel planes. The casting angles may constitute oblique angles that pass through several reconstructed 2D images.

[0011] The present invention contemplates processing the three-dimensional visualization 10 automatically in order to optimize the casting angle 20. One embodiment of the methodology contemplated is illustrated in Figure 4. The present invention begins by isolating the plurality of anatomical structures 16 within the three-dimensional visualization 10 (40). This can be performed through a variety of understood techniques. Simple thresholding or segmentation techniques are well understood methods for isolating anatomical structures 16 within images. Known segmentation techniques are also capable of automatically separating bony structures and separating them from the images. Once individual anatomical structures 30 are identified, a plurality of casting angles 26 can be evaluated.

[0012] The plurality of casting angles 20 are evaluated by calculating the number of ray

intersects 25 intersecting more than one of said plurality of anatomical structures 16 for each casting angle 20 (42). In addition to the number of ray intersects 25, the amount of ray intersect 32 may also be calculated. The optimum casting angle 26 is then selected (44) based upon the least amount of overlapping by minimizing the number of ray intersects 25 intersecting more than one of the plurality of anatomical structures 16. Although this may be accomplished through a variety of methods and algorithms, one embodiment contemplates selection 44 based upon minimizing the number of overlapped pixels in the display 46. If M_{α} is the set of pixels that will result in overlapped 3D images of a particular casting angle α , and: $M_{\alpha} = [(x_1, y_1, z_1), (x_2, y_2, z_2), \dots, (x_n, y_n, z_n)]$ where (x_k, y_k, z_k) represents the x, y, and z coordinates of pixel k, $k=1, \dots, n$. Then the casting angle α should be selected such that it minimizes the set M_{α} .

[0013] After selection 44, the optimized medical three-dimensional visualization can be displayed from the selected casting angle 48.

[0014] An alternate approach is illustrated in Figure 5. This approach makes use of the simple geometrical relationship of anatomical structure cross-sections 50 (see Figure 2). Once the anatomical structures are identified and isolated 40, this embodiment approximates the cross-section of each anatomical structure with a simple geometrical shape 52. The geometrical shapes 52 of the illustrated blood vessels 18 are illustrated as ovals, although a variety of geometrical shapes 52 are contemplated for a variety of cross-sections. Based upon the shape and location of these geometrical shapes the amount of overlap can be determined analytically for each of the casting angles 54. The optimum casting angle can thereby be selected 44 as before based upon the minimization of overlap. Again, a wide variety of simple geometrical calculations can be utilized to make this selection 44. And again, after selection 44, the optimized medical three-dimensional visualization can be displayed from the selected casting angle 48.

[0015] It is contemplated that there may be circumstances and three-dimensional visualizations 10 that may be make it impossible or exceedingly difficult to produce a 3D image without any overlapping. In these cases, multiple three-dimensional visualizations 10 are recommended. The embodiment illustrated in Figure 6 illustrates

the present inventions preferable approach to such scenarios. This embodiment isolates the plurality of anatomical structures 60 and evaluates the plurality of casting angles 62 in either of the above identified methods, or in alternate variations. A first 3D visualization is selected based upon overall minimization of overlap 64 again as previously discussed. This embodiment, however, calculates and stores the locations of anatomical structure overlap 66. A second 3D visualization is then selected based upon a new casting angle that minimizes the number of overlaps in the region of previous overlap 68. In other words, if a minimized pixel approach is utilized, a new projection angle β should be selected such that it minimizes the overlaps in M_{α} . The process can be repeated until the amount of overlap is less than a predetermined threshold 70.

[0016] Finally, although the previous discussions have approached the plurality of anatomical structures 16 as having equal importance, this is not always the case. As an example only, if the objective of the three-dimensional visualization 10 is to determine the viability of a kidney donor, anatomical structures 16 that are not part of the kidney structure will not carry the same weight as ones that do. Neighboring structures that might obstruct the view of the kidney itself may be deleterious as well. Therefore, the present invention contemplates an embodiment illustrated in Figure 7. This embodiment includes the step of assigning weighting functions (or penalty function) to different anatomical structures 72. This can be utilized in a variety of fashions. Slight overlapping of large vessels may be less weighted than the same size overlapping of small vessels. Percentage of overlap may be utilized as a weighting factor for minimization. Other utilizations, as discussed may weight overlap of relevant structures higher than those of insignificant structures. In addition, it is contemplated that structures obstructing the weighted anatomical structures may be automatically removed from the display altogether. This embodiment can be utilized in conjunction with any of the disclosed embodiments. It adds a further improvement to automated visualization.

[0017] While particular embodiments of the invention have been shown and described, numerous variations and alternative embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.